SHARP INTERFACE MODELS IN DELINEATION OF PETROLEUM TRAPS

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Surveying, prospecting and development of oil reservoirs in complex hydrogeological conditions calls for models able to incorporate the basic phenomena involved (Pascalian, Archimedian, and Darcian forces acting on hydrocarbon volumes) and simple enough to rely on existing geological data (Biddle and Wielchowsky, 1994). We develop such models and obtain simple explicit solutions based on the abrupt interface assumption dating back to DuCommun (1828).

Resting gas, oil and combined traps in equilibrium with moving water are studied by the methods of complex analysis (conformal mappings and the method of linear differential equations). Steady-state, Darcian, essentially 2-D flow patterns in homogeneous formations are addressed. For a monocline dipping at an arbitrary angle and one-phase trap two regimes (diffusor and confusor) are possible and explicit analytical solutions for the shape of a sharp interface between water and hydrocarbon are derived in terms of hypergeometric functions by conformal mapping of a lune in the hodograph plane onto a strip in the complex potential plane. The free surface is shown to coincide with the famous Taylor-Saffman bubble in the Hele-Shaw apparatus if the angle of inclination is $\pi/2$. Hydrodynamic solutions obtained are compared with the results of hydraulic models based on quasi 1-D flow schemes below the trap (Dalberg, 1982). The hydraulic models, being based on the Dupuit-Forchheimer assumption, are expostulated on their ignorance of important flow features.

For a gas-oil trap the interface consists of two branches along which the isobaric condition (in the gas aloft and extending infinitely far upstream) and the condition of linear increase of pressure with depth (in the oil part separated by a horizontal hydrostatic interface from the gas finger and by a curvilinear hydrodynamic interface from water) are reduced to a standard

hodograph representation through two touching circles. A critical regime is analyzed when the free surface does not have an inflexion point. For an anticline with constant thickness flanks dipping at the same angle upstream and downstream from the crest, the trap problem is solved by the method of Polubarinova-Kochina with reduction of the boundary-value problem to a Fuxian equation and examination of three flow regimes (Hobson and Tiratsoo, 1985).

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